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Final Technical Report

SUBMILLIMETER RADIATION FROM

RELATIVISTIC ELECTRONS

Grant No. AF-AFOSR-61-69

by the

Air Force Office of Scientific Research

of the

Air Research and Development Command

to the

University of Alabama

University, Alabama

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May 3, 1963

A. INTRODUCTION

Production of significant amounts of radiation at wavelengths of the order of a tenth of a millimeter presents a problem which is not yet fully solved. This work has been concerned with a method for utilization of a bunched relativistic electron beam for production of such radiation. In particular, the interaction of a bunched beam with the fields propagated by a corrugated cylindrical waveguide structure is being investigated. Design criteria for the waveguide structure have been devised. Cold radio-frequency tests have been made on structures scaled to C-band, and the results have been compared with theory. A structure scaled to 7.5 mm wavelength has been designed and is being electroformed.

Development of a linear accelerator for production of a bunched beam of 3-5 Mev electrons has been completed. This accelerator was built largely with funds from other sources, and only the final assembly and testing have been done under this project.

Calibration of an analyzing magnet intended to produce, by separation, a beam with small energy spread has been completed. This magnet is to be used in study of the energy dependence of the radiation.

Work continues under a new grant, AF-AFOSR-295-63. A graduate student is now engaged in an analysis of the beam-field interaction. It is expected that this study will be complete in time to permit, during the summer of 1963, comparison with results from a scaled-up structure. Results of these tests will guide the move to submillimeter structures. Meanwhile, wavelength- and power- measuring devices are being designed.

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The principal investigator and three graduate students are currently engaged in this Research. One graduate student has received a Ph.D. for his research on this project. One M.S. will be awarded in June, and a second probably in August of 1963.

B. THE SLOW-WAVE STRUCTURE

The type of interaction being investigated is a Cerenkov-type interaction between a bunched electron beam and the longitudinal fields in a corrugated metallic waveguide structure. A theoretical analysis of the fields propagated by this type of structure was undertaken with the idea of establishing methods of design for a desired phase velocity at a desired wavelength. Experimental investigations were made of structures designed for frequencies near 6000 MC/sec. Figure 1 shows the general configuration of the structure. One section, designed to be a scaled-up version of a submillimeter radiator had the following dimensions.

Length 4.701 in.

No. Disks 8

D/L 1/2

R 3.051 in.

H. 0.174 in.

Brillouin diagrams for several circular TM modes are shown in Fig. 2. The solid lines are calculated curves. The small circles represent modes which were identified and measured. Crosses indicate predicted locations of modes which were not actually identified. Agreement between

theory and experiment is generally very good. This structure is
capable of being scaled for a reasonable submillimeter radiator.
Results of this phase of the research have been submitted for publi-
cation in the Journal of Applied Physics.

A structure based on this design and scaled for 7.5 mm wavelength
is being electroformed from copper. After cold-tests are completed,
it will actually be used as a radiator in a test of the beam-field
interaction theory which is being developed. This theory is complicated
by the complex fields involved, but satisfactory progress is being
made toward its formulation.

C. THE ELECTRON ACCELERATOR

The accelerator structure is of the Stanford disk-loaded cylindrical
waveguide type with electrons injected at 80 Kv. A Sperry klystron
feeds the accelerating structure with pulsed power of 1-2 megawatts at
about 5900 Mc/sec. The accelerator is now in operation but the beam
characteristics have not yet been fully determined. Some difficulty is
being experienced with the oxide-coated cathode of the gun, and it may
be necessary to go to a bombarded-cathode construction.

D. THE ANALYZING MAGNET

Numerical integration of the electron trajectories in the acceler-
ator indicates a spread of approximately two per cent in the energies of
the emergent electrons. In order to reduce this spread and to determine
the electron energy, an analyzing magnet has been constructed and calibrated.
With a deflection angle of 45°, this magnet will accept electrons of

energies from 3-7 Mev, delivering an electron beam with an energy
spread of approximately 0.2%. Calibration has been accomplished by
approximate integration of the electron path in the field, which was
mapped by a motor-driven flip coil. The calibration was checked by
use of a current-carrying wire. The field is monitored by a proton-
resonance spectrometer located near the center of the field, and
calibration was made in terms of this field.

E. REFERENCES

1. W. H. Venable, "A Disk Loaded Waveguide Design for a Submilli-
   meter Radiation Generator," Doctoral Dissertation, University
   of Alabama, (1962). (An abridgement of a portion of this
   dissertation submitted for publication in the Journal of
   Applied Physics. A copy of the full text has been sent to
   the technical monitor of this grant.)

2. Frederick Curtis Breslin, "The Calibration of the Analyzing
   Magnet of a Linear Electron Accelerator," Masters Thesis,
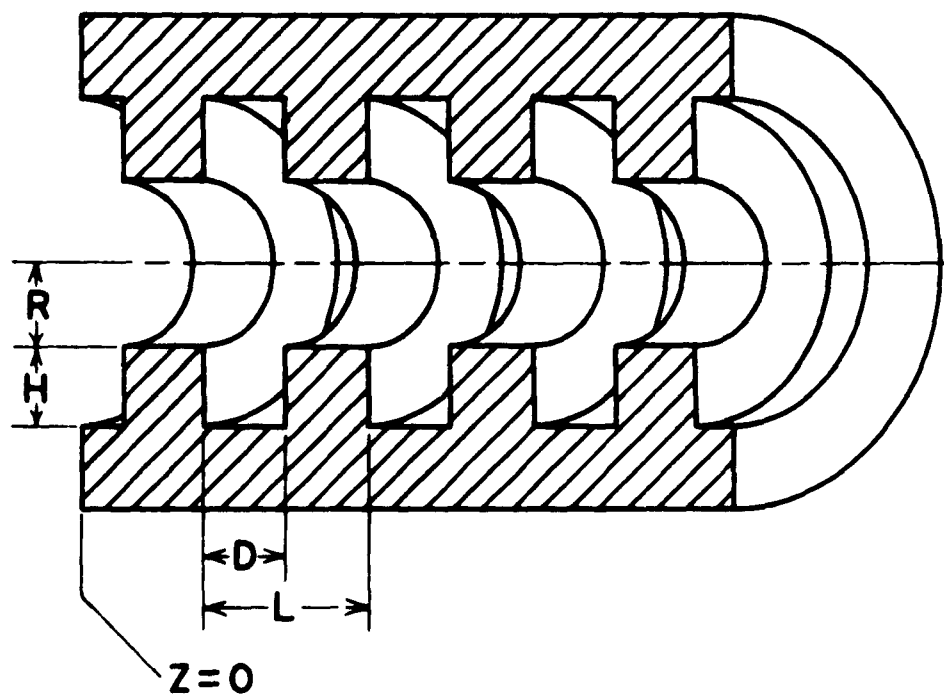   University of Alabama, (1963).

Fig. 1. A representative cross section of a four cavity
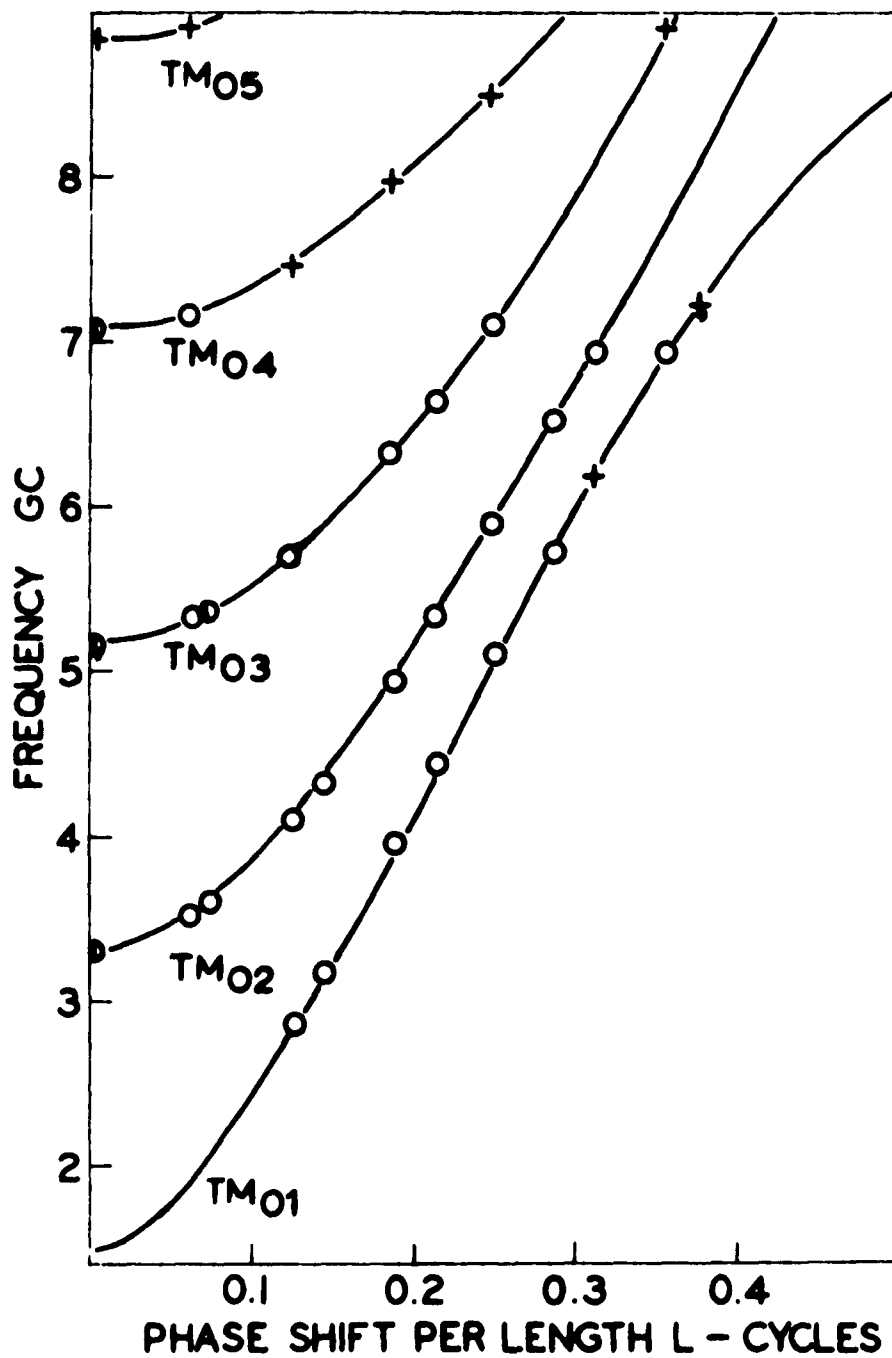length of disk loaded waveguide.

Fig. 2. A Brillouin diagram for Section J.

The circular points represent resonances which were completely identified, and the cross points represent resonances which were identified as to mode type but for which the wavelength was not measured.